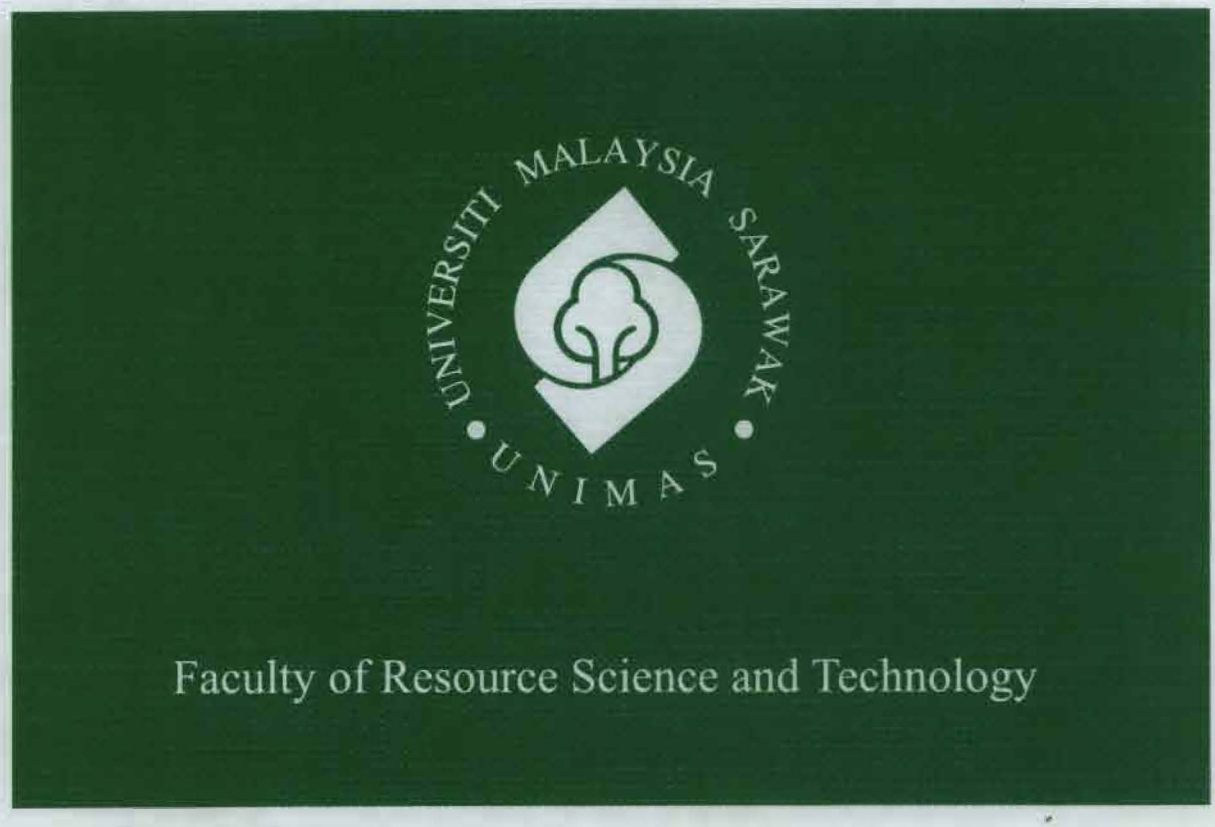

VERTICAL STRATIFICATION OF FRUIT-FEEDING BUTTERFLIES (LEPIDOPTERA: NYMPHALIDAE) IN A SECONDARY FOREST, KOTA SAMARAHAN, SARAWAK

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Vertical Stratification of Fruit-Feeding Butterflies (Lepidoptera: Nymphalidae) in Secondary Forest, Kota Samarahan

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DECLARATION

No portion of the work referred to in this dissertation has been submitted in support of an application for another degree or qualification at this or other university or institutions of higher learning.

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LIST OF ABBREVIATIONS

UNIMAS	Universiti Malaysia Sarawak
m	meter
sd	significant difference
ns	no significant difference

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ABSTRACT

The diversity and vertical stratification (ground: 1m above ground; canopy: 20-22m above ground) of the fruit-feeding butterflies were studied in a secondary forest located in the vicinity of UNIMAS East Campus, Kota Samarahan by using 10 baited traps. A single-rope technique was applied in 60 days sampling period. A total of 279 individuals from 33 species and four subfamilies were documented. Species diversity index was higher at canopy level with Shannon diversity index H'= 2.536. The overall total species richness and abundance reflected a declining pattern of Morphinae and Satyrinae which was observed as increasing heights and vice versa. The dominance was be represented by the Satyrine, *Mycalesis anapita fucentia* which is 21.5% (60 individuals) of the total number of individuals sampled. *M. anapita* was to be found at ground level. Nymphanlinae was the most specious subfamily at the canopy level representing 42.42% (15 species) of the total number of species, while Satyrinae was the most abundant subfamily, representing 41.58%. Charaxinae was found to be the lowest in both abundance and species richness. The secondary forest resulted a high proportion of Nymphalinae to canopy level and various pattern distribution of butterflies also were be observed.

Keywords: Fruit-feeding butterflies, Nymphalidae, secondary forest, Unimas

ABKTRAK

Kepelbagaian dan stratifikasi menegak Permukaan tanah: 1m di atas tanah; kanopi: 20-22m di atas tanah) rama-rama buah-makan telah dikaji dalam hutan menengah yang terletak di sekitar UNIMAS Kampus Timur, Kota Samarahan dengan menggunakan 10 perangkap berumpan. Satu teknik yang tunggal tali telah digunakan dalam 60 hari tempoh persampelan. Sebanyak 279 individu dari 33 spesies dan empat subfamili telah didokumenkan. Indeks kepelbagaian spesies adalah lebih tinggi di peringkat kanopi Indeks kepelbagaian Shannon H '= 2.536 Jumlah kekayaan spesies keseluruhan dan bilangan individu menunjukkan corak penurunan Morphinae dan Satyrinae yang telah dilihat apabila semakin meningkatnya kadar ketinggian dan sebaliknya. Dominasi telah diwakili oleh Satyrine, iaitu Mycalesis anapita fucentia yang merupakan 21.5% (60 individu) daripada jumlah keseluruhan individu yang telah disampel. M. anapita telah ditemui di permukaan tanah. Nymphalinae adalah subfamili yang paling banyak di peringkat kanopi yang mewakili 42.42% (15 spesies) daripada jumlah spesies, manakala Satyrinae adalah subfamili yang paling banyak individu, yang mewakili 41.58% . Charaxinae didapati yang paling rendah dalam kedua-dua bilangan individu dan kekayaan spesies. Hutan sekunder menyebabkan sebahagian besar daripada Nymphalinae ke paras kanopi dan pelbagai pengagihan corak rama-rama juga telah dikaji.

Kata kunci: Rama-rama pemakan buah, Nymphalidae, hutan sekunder, Unimas

CHAPTER 1

1.0 INTRODUCTION

Assessments on canopy biodiversity have been established around the world and these include the Global Canopy Programme (Butler, 2005). Most insect species are dependent on closed-canopy forests and yet the destruction of tropical rainforest is occuring at a rapid rate (Collin, 1990). Therefore, studies of diversity patterns are urgently needed in order to understand tropical communities and their conservation value (Holloway *et al.,* 1992). Due to accessibility problem, not many local studies had been conducted on forest canopy as sampling flying insects at this stratum is rather challenging. Many previous studies have taken place in primary forest, but curiosity to know the canopy entofauna sustained in disturbance area leads to this research.

Light is important in determining the distribution of many forest insects, and many insects including butterflies are vertically stratified from the ground to the canopy (Davis and Sutton 1998). Almost all butterflies are active exclusively during the day while the great majority of moths are active only at night (Glassberg, 1993). In addition, presence of host plants in the particular habitat facilitate larval growth and development as well as accesible to egg-laying females. Futhermore, pupation sites for mate location, places for resting, roosting and adult feeding should be present (Pullin, 1995). Distribution of butterflies species can be determined by the types of habitat that they occupy (Pullin, 1995).

By studying the fruit-feeding butterflies in a secondary forest, faunistic composition of this guild of butterflies could be characterized. Moreover, general patterns in the vertical stratification of the fruit feeding butterflies can also be produced. In addition, baited fruit-feeding butterflies are proven to be a good indicator tool in characterizing the habitat they sustained (Fermon *et al.*, 2000).

The technique to study the canopy level could be challenging, depends on the approach (Butler, 2005). This step is the most difficult part, as getting the tree crown could be the major problem. In this study, the baited traps were set up by utilizing the single-rope technique, where the traps were tied to the rope and the heights are adjusted to both canopy and ground level (1 m ground level: 20-22 m canopy level ; above ground level).

The main objective of this study are to investigate the overall diversity and abundance of fruit feeding butterflies in a secondary forest and to determine the vertical distribution pattern of this insects at two different levels. Besides that, this study also intend to conduct an observation on the dominant and least dominant distribution of butterflies.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Vertical distribution

The stratification of biota between forest canopy and understory is a significant factor contributing to tropical diversity (Hamer *et al.,* 2003). Previously, study on tropical forest canopy is a field that has been diversified in terms of principle and become an interesting entry. Some studies have suggested that there is a distinctive canopy fauna and that ground-based surveys miss a substantial component of forest biodiversity (Hughes *et al.,* 1998; Davis and Sutton, 1998). Several studies investigating vertical stratification in butterflies have demonstrated a distinctive canopy fauna compared with understorey, probably due to the differences in the light environment in the canopy compared with the understorey (DeVries *et al.,* 1997; DeVries *et al.* 1999; Beck and Schulze 2000; Hill *et al.* 2001). However, studies on butterflies in the canopy are still lacking, particularly in South East Asian rainforest (Hamer *et al.,* 2003; Hughes *et al.,* 1998; Schulze *et al.,* 2001).

Recent progress in canopy had resulted to the most significant development in canopy entomology. The scope of canopy study was well developed and the precisely methods to access the canopy had also been improved. There are several studies that lead to vertical methods, and it seems that the population of fruit-feeding butterflies have shown higher diversity at ground level, compared with the canopy (Hughes *et al.,* 1998). Probably due to the presence of rotting fruit at the ground. Based on previous studies done, diversification

in terms of methodology has been well improved (Basset *et al.,* 2005). On the other hand, analysis of vertical distribution patterns, especially in the multi-layered type of forest will assist in understanding the species composition in butterfly communities (Schulze *et al.,* 2001).

According to Allee (1926), the distribution of species at particular heights within forest communities, referred to here as vertical structure, is a classic phenomena in ecology. The abundance distribution of the fruit feeding butterflies shows that the nymphalids community was vertically structured. There are several methods available to monitor rainforest butterflies, each with their own drawbacks (DeVries and Walla, 2001). In particular, passive traps baited with rotting fruits attract adult butterflies of certain species in that they imbibe fermenting fruit juice. Some families may occur most on the canopy such as Nymphalinae and Charaxinae and some may occur in both strata (DeVries and Walla, 2001). For example, both of those subfamilies usually mostly occur in the canopy level, while Satyrinae and Morphinae are mostly found at the ground level.

2.2 Secondary forest (Disturbance area)

Degradation and fragmentation of tropical rainforest habitats is a major issue in conservation biology, concerning the protection of species diversity. Fragmented area are those that were once disrupted primarily by human disturbances, such as land clearing and changes of crops (Kremen, 1994). Many studies have shown that tropical butterfly communities also respond to physical factors of the habitat, such as topography, stratification, gaps, edges, urbanization and habitat disturbances (DeVries, 1988; Hill *et al.,* 1992, Raguso and Llorente-Bousquets, 1991; Ruszczyk, 1986).

Most plant and animal species in the tropical forests exhibit stratified distributions between canopy and understory (DeVries, 1998, Sutton and Hudson, 1980). The forest edge and intermediate disturbance forest presented higher values of butterfly species richness and diversity. These environments, where intense regeneration occurs, have high productivity and maintain high population levels (Ramos, 1996). Alternatively, the vegetation structure of disturbed forest is suitable for sun-lovers, secondary and opportunistic species that may spread throughout the region (Ramos, 1996). Among insects, butterflies are proven to be invaluable flagship species for conservation (Thomas, 2005). Butterflies demonstrate a hierarchy in host preferences, discriminating among plant species, among genotypes, among individuals with different phenological and physiological conditions, and even among plant parts (Wiklund, 1984).

The Bornean forest are well known as centres of insect diversity and much effort has focused on the population of butterflies in order to generate and maintain this diversity (Schulze *et al.*, 2001). On the other hand, the amount of sunlight that penetrate through are most likely contributed from the forest gaps which could be from the less dense part of the canopy, or obviously from forested area (Christharina, 2008). As the butterfly love to sunlight, the presence of sun-loving butterfly species is increased with the high amount of light intensity (Ipor *et al.*, 2006).

There are five different groups of fauna that can be divided according to their habitat and feeding behaviour (Abang and Hill, 2006). These habitats are the aquatic, soil, tree trunk, dead tree trunk and tree canopy. Amongst all the biota, the butterflies are very sensitive to modification of habitat, humidity and moisture conditions and thus, most specialized and native butterflies have disappeared from culturally modified habitat of tropical forest

ecosystems (Hill *et al.,* 2001). Usually, the organism especially insects will continue to survive depending on what or where they can eat (feeding niches) and their ability to reproduce. Some sensitive species of butterflies respond rapidly to environmental changes (Fox *et al.,* 2007). This makes butterflies good indicators of habitat loss and fragmentation, and the impacts of climate change (Brereton *et al.,* 2011; Fox *et al.,* 2007). Based on previous studies, it was concluded that, among all insects, butterflies are highly sensitive to habitat disturbance and have been used commonly as an indicator taxon for ecological research (Kremen, 1994; Koh and Sodhi, 2004).

Butterflies are comparatively well studied. According to Spitzer *et al.,* (1993) and Hill *et al.,* (1995), butterfly species composition in disturbed and undisturbed forests has been investigated for example in Southeast Asia and the Neotropics (Lovejoy *et al.,* 1986; Brown *et al.,* 1991; Sparrow *et al.,* 1994; DeVries *et al.,* 1997; Wood and Gillman 1998). Several studies showed that low disturbance levels have a positive effect on diversity and abundance of rainforest butterflies (Lovejoy *et al.,* 1986; Brown 1991; Sparrow *et al.* 1994; Wood and Gillman, 1998). Species with a restricted geographic distribution appear to be more sensitive to human disturbance and forest structure changes than widespread species (Sundufu and Dumbuya, 2008).

In South-East Asia, the greatest impact of habitat disturbance is on forests in the Malay Archipelago, including the island of Borneo (Hamer *et al.,* 2003). In the Malaysian state of Sabah (northern Borneo), most remaining forest is reserved as production forest and designated to be selectively logged (Whitmore, 1991). In this study area, the availability of light intensity is high due to natural gap creation. Light is known to be an important abiotic factor influencing the distribution, biomass and diversity of terrestrial plants and animals

(Begon *et al.*, 1998). In addition, the suitability of temperature also affects the distribution of butterflies where the tendency at their presence is seen when there is an occurence of light.

2.3 Fruit-feeding butterflies

Butterfly is a well studied insect taxon across the world since it is a sensitive insect group to habitat disturbance and this plays a very important role in the ecosystem (Tabadepu *et al.*, 2008). Amongst all the different groups of insects in the tropics, butterflies are probably the best known group. Their variation in colors and unique in complexion have tempted people's curiousity of all times to take a closer look. However, there are still a lot of butterfly species which has not been studied. Most family of lepidoptera are feed on nectars, but certain group members are frugivorous.

According to DeVries and Walla (2001), adult butterflies in the family Nymphalidae are attracted to feed on the juice of rotting fruits and thus, they are referred to as fruit feeding nymphalids. Based on a study that has been done in Poring, Sabah, Schulze (2001) . The occurence of fruit-feeding nymphalids at the ground level was significantly parallel with the abundance of rotting fruit. Identifying butterflies species when they are in flight is difficult and therefore, the study focused on the guild of fruit feeding butterflies that could be caught in traps baited with rotting fruits (Hill *et al.*, 2001; Hamer *et al.*, 2003).

On the other hand, according to Fermon *et al.*, (2001), the alteration of microclimatic conditions are due to the changes in the vegetation structure, such as temperature, rainfall and humidity, and it will give effects to the butterfly feeding activity (Haber, 2005). Another

factor that influenced by microclimate are the diversity and abundance of butterfly food plants, along with the development of larval (Fermon *et al.,* 2000). In addition, some groups of butterfly emanate to be abundant and certain less in number, due to the microclimate. Butterflies are affected to any changes in environmental gradient, notably in the tropical region (Hill *et al.,* 2001).

The main factors that most likely influenced the survival of butterflies are temperature and rainfall, these are via effects on plants growth, predation and diseases (Pollard and Yates, 1993). Besides, the influence of rainfall to the abundance and distribution of butterflies can just coherently be seen in the tropical region, where the rainfall is consistently high and affecting seasonality (Hill *et al.,* 2001). This factor cannot be used in the temperate region, yet with the variant changes in temperature, well known year to year fluctuation in butterfly population can still be observed (Hill *et al.,* 2001).

According to Schulze *et al.,* (2001), the important factors that lead to the specialization of butterflies on certain strata is the larval resources. Typically, most butterflies only occur at certain area where the sources are available, and are host-plant specific. All the factors that lead to the differentiation of butterflies across the vertical gradient are the distribution of the variations in microclimate, adult resources and the presence of predators (Schulze *et al.,* 2001).

Tropical butterflies are different among each other in terms of morphology and habitat connection in relation to phylogeny (Hamer *et al.,* 2003). Based on past studies, the design of body or the morphology of adult has been linked and analyzed as an indicator for their flight characteristic (Schulze *et al.,* 2001). The geological location and tropical climate of Borneo has led to speciation and great diversity (MacKinnon *et al.,* 1996). The Bornean rainforests

eventually accommodate a tremendously high Lepidopteran diversity (Abang and Karim, 2005). The present study, focused on fruit feeding butterflies of (Nymphalidae). In Borneo, the number of butterfly species is related to the biological plants within the region (Otsuka, 1998). Most Bornean butterflies remain hidden in the upper canopy where nectar bearing flowers occur whereas the rest would prefer living in open secondary forest (Yates, 1992).

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Study site

A study on vertical stratification of fruit feeding butterflies was conducted at a secondary forest located at Universiti Malaysia Sarawak, Kota Samarahan (110 ° 26' 50.5 E and 1° 27' 56.4 N). This study site consist variety of palms species plants. This is significantly proven by the secondary growth, which are the denser undergrowth of smaller trees and climbers (Abang and Hill, 2006).

3.2 Methodology

3.2.1 Butterfly sampling

Bait trapping was carried out with cylindrical gauze-traps (Schulze *et al.*, 2001) tied at two distinct phases. The baited traps was designed to entice butterflies with aromatic bait towards the trap (Austin and Riley, 1995). The trap itself is designed to exploit the escape response of most butterflies to fly upwards trap (Austin and Riley, 1995). Nevertheless, these traps usually attract the subset of species that feed on fruits (Caidas and Robbins, 2003). The traps were to hung at the from ground level (one meter above ground) and at the canopy level (20 m to 23 m). All baited traps were installed by using the single rope technique. The rope was shot by using a slingshot to the branch of tree at canopy level and then adjusted to proper height. Five trees were be selected in 15 meter approximately in distance between each tree. Two traps for each individual trees were chosen, and thus there were ten traps in total.

Rotting bananas and ripen pineapples were used as baits, which were replaced alternately every five days. The efficacy of the use of rotting fruits due to smell and odour, was proven by previous studies (Beck and Schulze, 2001; DeVries and Walla, 2001; Haber, 2005). Based on DeVries and Walla (2001), by using the rotting fruits, the fruit feeding butterflies will be easily sampled either in spatial or temporal dimensions.

This research was carried out for 60 consecutive days, starting from 1st February until 2nd April 2013. The butterflies were checked the following day after the traps were baited with

the rotting fruits. On each sampling day, all the traps were checked in the evening (between 1600 hours until 1800 hours).

3.2.2 Mounting and preserving

The samples were preserved, and the wings were spread on the spreading board and aligned in perpendicular level to the body (Abang and Karim, 2005). The specimens were carefully handled and any hard samples were first relaxed inside the relaxing jar and was left overnight during the process. The specimens were identified and labeled with the date of collection, species name and level above the ground, and kept on polystrene board. To further preserve the specimens, samples were kept in closed container and with naphthalene balls.

3.2.3 Identification

The samples were identified to species level following Otsuka (1988), a pocket guide of butterflies of Malaysian Borneo (Abang, 2006) and the UNIMAS Reference Collection. The number of individuals for each subfamily were recorded and all samples were placed at the UNIMAS Insect Reference Collection.

3.2.4 Statistical analysis

Shannon index and Paired Samples T-test were used to measure and to compare the diversity index (Krebs, 1989) and the mean for the species and individuals of fruit-feeding butterflies at ground and canopy level. These statistical analysis was performed by using the Power Analysis and Sample Size and SPSS 11.5 software.

CHAPTER 4

4.0 RESULTS

4.1 Species diversity and abundance distribution

4.1.1 Overall species diversity

A total of 279 individuals of fruit-feeding butterflies representing 33 species from four subfamilies were sampled at the secondary forest in the vicinity in Universiti Malaysia Sarawak East Campus, in Kota Samarahan, Sarawak. An average of five individuals were recorded per day throughout the sampling period. Several of them were *Mycalesis anapita fucentia* which rerepresenting 21.54% (60 individuals), *Zeuxidia amethystus wallacei* 15.10% (42 individuals), *Zeuxidia doubledayi horsefieldii* 14.33% (40 individuals) and *Prothoe franckii borneensis* 8.60% (24 individuals). Three of them were mostly captured at the ground level, while *P. franckii* was sampled equally at both ground and canopy levels which representing 8.60% (12 individual respectively). Species diversity measures with Shannon-Weiner index reveal higher species richness at the canopy level (H' = 2.536) (Figure 4.1).

Satyrinae was the most diverse and abundant subfamily, representing 30.30% of the total nymphalid species recorded, and 41.58% from the total individuals trapped (Figure 4.2). *M. anapita* was the most abundant species for Satyrinae, with 60 individuals sampled

the other hand, Charaxinae was the least diverse and abundant subfamily captured in this study (Figure 4.2).